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THE PSYCHOLOGY OF MAN AND TECHNICAL PROGRESS

by A. N. Leont'yev and D. Yu. Panov

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THE PSYCHOLOGY OF MAN AND TECHNICAL PROGRESS

- USSR -

[Following is a translation of an article by A. N. Leont'yev and D. Yu. Panov in the Russian-language periodical Voprosy Filosofii (Problems of Philosophy), No 8, 1962, pages 50-62.]

The guiding prospect and ideal of the building of Communism is man. "Everything in the name of man, everything for the sake of man" -- this diction in the CPSU Program, revealing the inner motive of the history making progress of our society, also constitutes the primary guideline in development of science. In particular, a new development impetus is imparted to the sciences concerned with a direct study of man as such, and among them of steadily increasing importance are becoming the sciences dealing with the most complex manifestations of man's vital activity -- psychology and physiology of higher nervous activity.

An attempt to approach some theoretical problems of psychology arising in connection with prospective developments of the principal activity of man -- its work activity, which effectuates the process of material production, is precisely the topic of the present report.

1

In the course of work, in the directly productive activity, takes place the initial formation of the form of psychic reflection which is specifically inherent in man -- of its intellect. Thus, work constitutes the initial decisive factor, as well as the embodiment of spiritual, psychic development of people. It is in this sense that K. Marx refers to the history of industry as an "open book" in which is perceptibly revealed to us the human psychology (see Iz Rannikh Proizvedeniy [Selected

[Early Works], 1956, page 594).

The pre-Marxian science of psychology was unable to read this book. The divorce of mental work from physical, which induced spiritual withering of physical work, was reflected in psychology by the fact that the scope of its study was confined exclusively to the domain of purely mental activity, without inner connection of the latter with work, with the development of social production. Work in its basic form, in the form of production of the material values, was considered only from the standpoint of its purely external relationship to man. Man, taking part in production processes controlled by material, mechanical laws, was considered only in one of its aspects -- as subordinate in his work activity to these laws.

Therefore, to the end of the past century the psychology did not study at all man as an individual of material production. Psychology of labor did not exist. Although under the conditions of mechanical production of that time the labor activity of a worker was reduced mainly to a performance of monotonously recurrent external motive operations, the steadily more urgent necessity of intensifying the work brought to the fore the problem of maximal increase of efficacy and coordination of the functions performed by worker and machine. In response to this problem arose the so-called Taylorism and industrial psychotechnology. They undertook the study of such problems as the possible tightening of work schedule by elimination of superfluous motions and greater work proficiency, the determination of most convenient shape and dimensions of handles of manually operated tools and machines, the more efficient arrangement of operator's stands, and the like. Concurrently, work was in progress, on a steadily increasing scale, on selection of workers on the basis of their skill, which was aimed at recruiting for production work, from the available reserve of labor force, the people best suited for performance of the required work functions, that is of people the exploitation of whom would yield the greatest gains to the employer.

In assessing the Taylor system (and this appraisal may be legitimately extended to include the psychotechnology prevalent abroad, at that time), V. I. Lenin expounded its dual nature. He wrote that the Taylor system "combines the refined atrocity of bourgeoisie exploitation and a number of greatest scientific achievements in analysis of mechanical motions during work, elimination of superfluous and awkward motions, development of best work practices, maintenance of best systems of accounting and supervision, etc." (Collected Works, Vol 27, page 229).

An essentially entirely novel stage of development of work psychology, notwithstanding its sequential connection with the former psychotechnology, was initiated by the so-called engineering psychology (or "human engineering", ergonomics), which developed in its present-day form after the Second World War. The decisive role in the evolvement of engineering psychology was played by rapid development of complex technical equipment in industry, aviation and other forms of transport and communications, and also by the rapid development of electronics, cybernetics, and information theory.

The technical progress has revealed with particular emphasis the importance of the "man and machines" problem. It has imparted a new meaning to this problem. While under the past conditions the questions of matching the work of man and machine could in most instances be resolved on the common sense basis and required determination of relatively elementary anthropometric data, and some selection on the basis of skill, under the conditions of employment of a complex equipment the resolution of these questions was found to be impossible without special studies. Already during the war years the operation engineers and technicians encountered a number of unusual, not readily explainable errors committed by military personnel while using military machines and mechanisms. To determine the causes of the occurrence of these errors, and in the search for means of eliminate them, resort was had to psychology. It was in this manner that it was ascertained that complex equipment often taxes man with such demands that the satisfying of them necessitates a profound study of man's capabilities, in order to bring them in harmony with the capabilities of the machines. The working out of these problems was the most important tenor of the engineering psychology.

As a result of advances in production mechanization, which have made it possible to relegate to the machines the overwhelming part of motive operations formerly performed by workers and constituting the main, most clearly manifested portion of their work activity, of foremost importance became the inner, psychic functions, primarily the sensory functions. While the "execution part" of the work processes underwent simplification, the processes of perception, and processing of perceived data, became steadily more complex and "load-carrying". This led to the numerous studies of man's perception, aimed at an amelioration of instrument reading scales, their mutual arrangement on indicating panels, etc.

Although these investigations had primarily narrow, applicatory objectives, their general psychological,

theoretical significance soon became apparent. It was found first of all, that the previous approach to perception processes, and the very concepts relied upon to define them, are inadequate for encompassing the new and sometimes unexpected results which were obtained in these studies. There arose, for example, the problem of quantitative evaluation of the volume of perception by man of the various signals incoming to him. Since this problem could not be resolved by a simple computation of the number of stimuli signals effectively perceived per unit of time, the necessity arose to resort to methods developed in the information theory for solving analogous problems in the technical communication systems. Together with introduction into psychology of information-theory measurements, which determine the probability of occurrence of any given signal, the statistical (probability) approach became a widely utilized practice also in the investigations aimed at elucidation of the very nature of perception processes.

A still more important role was played by the fact that new foundations were provided for the standpoint of regarding perception as a relatively independent process, constituting not merely the initial link of a reflectory event, but a complex and relatively "completed" functional system which comprises numerous central and efferent links, a system having its own specific regulation and its own specific product in the form of an integral image of the object actively differentiated within the external field, or in the form of an also actively differentiated separate parameter of any given influencing complex.

Inseparably from the problem concerning the amount of information received, arose the problem of study of the processes of its handling by man, which were found to approximate in their complexity the most subtle processes ever investigated in psychology. It is sufficient to refer, for example, to the data of investigation of the various strategies the employment of which is necessary for the recognition and classification of complex perceived objects.

Thus the development of investigations in the field of engineering psychology brought out a most important fact: the more the work functions were converted to the function of control of the machines, the more fully became apparent their psychological cognition tenor; and the more was revealed, behind the outward motion acts performed by the worker-operator, the huge and often very intensive inner mental work effected by him.

One should not assume, of course, that the above stated alteration of the functions performed by the worker

in production, imparted for the first time a psychological tenor to work processes. It merely revealed the psychological tenor inherent in any work process. Even the most simple acts of work, consisting of repeated outward motions, have a complex physiological and psychological regulation.

The analysis of the content of current engineering-psychology investigations permits to differentiate still another, third stage in the studies of man's work functions. Although the problems which are characteristic of this stage arose already during the period when engineering psychology was only in a state of formation, and it is difficult to indicate chronologically its beginning, in its fully developed form it is outlined with sufficient clarity. This is the stage of resolution of the problems which confronted psychology on further advances of the automation of production.

The creation of complex technical systems of automatic control was of the nature of a shift of the boundary which separates the functions of man and machine. Such functions, for example, as recognition of objects, working out of optimal solutions of operational problems, etc., were consigned more and more to the machines. As a result the problem of correlation of the functions of man and machine moved to another, still higher level: it was found that it was necessary to bring in agreement the higher psychic functions of man and the functions, analogous to them, performed by automatic devices. This, of course, introduced new problems not only in psychology of work, but also in the general theory of psychology. We will consider only some of these problems.

2

Complex, semiautomatic systems of control are based on the principle of a distribution of functions between man and the technical cybernetic devices which effect an activity comparable to the higher nervous, psychic activity. For a matching, under these conditions, of the work of both "units" of such a system (operators and machines) the study of particular characteristics of man, for example of his carrying capacity or interference resistance, was no longer sufficient. The necessity arose to ascertain the structure and inner mechanisms of his psychic activity, in order to make it possible to carry out technical simulation of those processes which it is best to consign to the machine. On the one hand, the proposed independent basic diagrams of the automats being designed required an analysis from the standpoint of their equality to that psychic activity of man which they are

hypothetically simulating, and with which they should merge into a single system. On the other hand, such a hypothetic simulation becomes a method of investigation of the specific nature of the psychic activity as such, by means of a comparison of its capabilities with the capabilities of technical simulators.

The accumulated experience with technical simulation of psychic functions permits at present to ascertain with sufficient clarity the existence of serious mismatch between capabilities of man and capabilities of modern, actually existing automatic machines. This mismatch should not, by any means, be obscured by a reference to the theoretical prospect, so to speak, of exhaustive mathematical and technical simulation of all vital manifestations, including also the psychic manifestations. On the contrary, it is precisely from the standpoint of this prospect that the discovery of such a mismatch is of greatest heuristic importance to cybernetics as well as psychology.

It is well-known that to date there have been developed "perceiving automats". Such are, for instance, the perceptrons ("Mark II" and others), matrices of K. Shteynbukh, reading machines, vocoders, and other devices. However, they are actually recognizing machines, capable of recognizing a definite class of objects, which were fed into them during the process of their "training" or "self-training". There are as yet no machines capable of actual, visual perception of objects. Modern psychological studies have shown that the structure of the process of perception of objects includes, in addition to other operations, as its principal link, the operations of active differentiation in the object of its sensory content (shapes, features, colors, etc.) necessary for the purpose of perception. It is precisely the process of differentiation of this most "informative" content, that is not effected by the modern automats.

Even such specialized operations as the reading of a lettered text is effected by the presently available machines, so far, in a manner that is not perfect. It is sufficient to mention that the occurrence of interferences in the presence of which the perception of a text by a man is practically fully retained, renders recognition of the letters by the machine almost impossible. Bartlett has pointed out that man can read a text when the lower half of the lines is completely covered or removed; a task which is so far impossible to the recognizing machines. This capability of a man is due to the fact that in a reading person the inadequate information contained in the incomplete graphic representation of the letters is combined with vast excess information contained in the

meaning content of the text.

Thus, at first sight, we have a paradoxal situation. Man's perception is characterized by the fact that it is capable of functioning with inadequate informative signs contained in the object; at the same time it is capable of utilizing a vast information which, however, is not directly coded in the signs of the objects. This is, precisely the explanation of the occurrence of such effects as the adequate perception by man of double-meaning images; the "solving" of puzzle-pictures without prior knowledge of any signs of the object concealed in the picture, etc. It is obvious that the basic scheme of the perception processes performed by man and by modern machines are not coinciding with one another.

This is completely evident, in particular, in the case of reading of a text. The available data show that the eye of the reader does not come to a stop at each letter, but only at one out of four to six letters; in this displacement the eye effects numerous inversions of the text, that is, the gaze comes to a rest at first on, let us say, the third word of the line, from the left; then it moves to the beginning of the line; then moves forward, that is, to the right; then moves again in the backward direction, and so on. This is entirely different from the manner in which the analogous process takes place in the machines.

Even the foregoing cursory comparisons of the capabilities and methods of perception by man and by modern machines, permit to reach the conclusion that the schemes of the latter do not adequately simulate the corresponding processes occurring in human brain. These schemes depart from the psychological fact that the specific product of human perception is the image of the object, and not the code of its signs used in the solution of a definite problem. Is it legitimate to make such a distinction between the image of an object and the code of its signs? We believe that it is not only legitimate, but absolutely necessary, even on leaving out of consideration, for the time being, the importance of this distinction from the standpoint of theoretical cognition.

The gist of the matter is, that the principle of signalization, which is the basis of any code, even though it is at the same time the principle of reflection, is not however its only principle. The image as a result, as a subjective product of perception (we mean an image in the broad meaning of the term), can be transmitted by a code, but the image itself is not a sign, not a conventional, not a hieroglyphic transmittal of the real thing, but its reflection, comparable in its fullness with

the real thing being reflected. This brain-recreated reality -- past, present, or appearing as prospective, as an aim -- becomes the inner, ideal "operator" of man's activity, including the activity of the perception. If this refers to conscious representation, then it can also be the object, and at the same time the result of inner mental, purposeful actions of man; man is mentally comparing and combining with one another, or dissociating, the represented objects, modifying them in accordance with the problem that confronts him.

The mental actions thus accomplished are indeed actions, having the same fundamental structure as the outward objectival actions, a derivate of which they are. They are also "closed" by a link, which is the objectival reality, with only this difference that in such a case it appears in its reflected, "copied" form, and is therefore incapable of physical resistance to action and of outward, compulsory correction of it. For that very reason, incidentally, the result of inner actions requires a verification by practice.

It is evident that the physiological mechanism of this psychological reality can be only the reflectory processes of the brain, which form a structure that is also "closed" by objectival reality. Such are the structures described in the concepts of inverse afference at objectival level (sensorial syntheses, acceptant actions of P. K. Anokhin).

The existing automats reproduce the general scheme of these structures. It is another question, as to whether into this scheme can be introduced a cybernetic simulator of such an ideal operator which is capable to manifest itself selectively in every instance (that is, depending on the "context" meaning), as is provided by the image. In any event this requires a much more thorough knowledge of the structure of the processes of human perception, than the available knowledge. Encouraging is the fact that at present serious efforts are being made, universally, in the direction of an objective investigation of these processes, and a number of very productive hypotheses are being advanced. Therefore it may be assumed that substantial advances will be achieved along these lines in the near future.

Not less instructive, and of not less heuristic significance, is a comparison of human memory with the memory of a machine.

Simulation of memory yields greatest practical results. Modern machines have a very high rate of memorization, are capable of storing for any length of time, within the practically needed limits, the retained

material (the so-called "long-time memory") and of reproducing it with flawless accuracy. Finally, they have also a sufficiently large volume of memory -- up to 10^8 binary units.

It is remarkable, however, that all this notwithstanding, in the procedure by which machine memory is operating, and consequently in its functional capabilities, it is still less similar to memory of man than machine perception is to human perception. The gist of the matter is, that machine memory simulates only a particular mechanism thereof, namely the mechanism of formation of engrams, that is, of traces capable of reproduction. This mechanism constitutes an indispensable condition of operation of human memory, but the principle of operation of human memory is the principle of sensible memorizing and reproduction. Only in isolated, most exceptional instances, the mechanism of engraving becomes foremost in memory, and it is precisely in such instances that are revealed most evidently all of its limitations and even its "unnatural character" insofar as man is concerned.

To give a striking illustration of this, we will describe a peculiar experiment performed by one of us several years ago. It was carried out in conjunction with a lecture on memory, delivered to an audience of advanced training, at which were demonstrated the most unusual mnemonic faculties of S. V. Shereshevskiy, which have been described many a time in psychological literature. The experiment, with which we are concerned, was as follows. After a long series of random words had been read aloud, once, to S. V. Shereshevskiy, and was repeated by him, without an error, according to a specific program (from beginning to the end of the series; then from the end to the beginning of the series; then from the middle of the series, alternately, to the beginning and to the end, etc.) the following problem was given to S. V. Shereshevskiy and at the same time to the entire audience. It was required to find an answer to a question concerning one word of the series; it was agreed that Shereshevskiy will answer the question aloud, while every member of the audience who has mentally determined the necessary answer, will immediately raise his hand in silence. Thereafter the following question was asked. Which of the words of the series submitted for memorizing, and then repeated without an error, means an infectious disease? (The word in question was "typhus".)

This experiment had the following result. Immediately after the last two words of the submitted question had been spoken, many hands were raised in the audience. At the same time it could be seen with what an effort the

answer was sought for by Shereshevskiy: with eyes shut, with characteristic motions of the half extended hands, as if groping through the words of the series, etc. Only after many seconds had elapsed, was the word "typhus" spoken out. Later on, Shereshevskiy told that he had mentally gone over the series of words, but, in a hurry, had missed the needed word on first attempt, and had to go over the series a second time.

The "machine" principle of memory, which under the conditions of this demonstration was relied upon by Shereshevskiy, revealed most strikingly its limitations in comparison with the meaning principle of operation, specific of a normal human memory, which evidently is also controlled by that ideal "operator" which is the image.

Still more complex is the problem of simulation of thinking. Here we come upon the fact that the originators of machines, in some cases, visualize the processes of human thinking in an insufficiently complete manner. For example, the operative definition of thinking proposed by Thuring is, from this standpoint, clearly unsatisfactory, since the choice of a correct answer to a question does not amount to thinking. Without discussing here the question, as to whether human thinking amounts to the performance of such operations as, for example, the demonstration of the theorems of geometry, theorems of mathematical logic, translation from one language into another, etc., which to date can be successfully carried out by a machine, we only wish to emphasize that the possibilities of simulation of thinking are, at the present time, practically limited to those mental operations for which it is possible to find a single-valued system of rules (algorithms). On the other hand, the development of machines capable of plausible deductions, in the meaning of Polya, and of making correct decisions on the basis of inadequate data, encounters up to now insuperable difficulties.

In fact, the "thinking" machines operate not with linguistic objectal values, not with a language, but with computation, that is with a certain set of rules, with a formal system devoid of objectal tenor, which is evolved according to the following principle: a) an arbitrary "alphabet" is prescribed, b) initial "words" in this alphabet are prescribed, c) rules are prescribed for the formation of new "words" from the initial. As a result, the objects, the operation with which is automated in the machine, appear as elements of prescribed operations, but within the scope of performance of the machine their objectal tenor remains blank. In human thinking, on the other hand, the meaning of objects is determined not only

by logic correlations, but also by their objectal tenor, and by the psychological situation within which are developing the actions of man; by his intentions and motives, by his relationship to the problems, etc. Hence, human activity in working with any technical system consists in imparting meaning to the signals delivered by the machine, for the purpose of determining the objectal tenor of received information, and the selection, on this basis, of the required action. Since the latter constitutes the main link in the whole chain of processes, which can not be eliminated, many authors on proposing mathematical formulas for the "criterion of rational choice of action", introduce parameters the values of which are determined by the capabilities and potentialities of the acting man. The necessity of introduction of these, so to speak psychological parameters shows that in this instance also we can not, as yet, adequately simulate human activity.

Thus, in summing up, it can be said that at present the advances in simulation of psychic activity of man are very slight; its basic characteristics are not reproduced by any machine built up to now. There is, all the more, no machine analogy for the fact that in the case of man it is always of importance how cognizant he is of his work. It is common knowledge, for example, that the "output" of a person can be greatly increased by provision of an appropriate goal. But the development of a machine having such truly human characteristics is apparently just as difficult and remote as an artificial creation of life capable of producing a thinking and conscious being.

Of course it is easy to point out, on the other hand, some characteristics of machines which can not be reproduced by man. It was stated hereinbefore that there are many things which the machine does better than man. However, probably the most consummate characteristic inherent to all machines, but not to man, is the possibility of preservation of the machine under the conditions when it is not operating and is not subjected to external influences. Yet it is impossible to keep man in "perfect order" under such conditions.

It is well known for example how man is affected by prolonged isolation and compulsory inactivity. It is found that if man is kept under conditions of sharply reduced auditory and optic stimuli, symptoms rapidly set in of serious disturbances of his psychic state. There develop, as is shown by data cited in the review article of Hood, visual, and under certain conditions also auditory hallucinations. Man can not with impunity, feel nothing and do nothing; he must be active. And this characteristic, of which machines are fully devoid, expresses apparently his utmost nature. Human nature

of man is the product of his historic development, precisely as a subject of active, transformant, conscious activity, as the only true subject of work.

3

The considering of man as a particular link included in the system of automatic devices and machines, makes it possible to resolve very important problems concerning the increased efficiency of the operation of this system. In conceding not only the legitimate nature of such an approach, but also its necessity, one should at the same time also emphasize its limitations. The limitations of such an approach are due to the fact that it is abstracted from the social nature of work and from the social nature of man as its subject -- a circumstance that can not be disregarded, not only in the working out of the broader theoretical problems, but also within the scope of the "man-machine" problem.

It is precisely the disregarding of this circumstance that has led to the views which consider the man as a mere link of an autonomous, in principle, complex of machines generated by the machines themselves, of a link that still remains, in a most vexing manner, unreplaced by automatic devices. The changes of the functions of man in production, caused by the course of technical progress, are considered by the proponents of these views as an alleged indication of the occurring elimination of man from the sphere of production. However, the idea of a progressing "dehumanization" of work is actually only reflecting its practical alienation, induced by dominance of conditions of private property.

At present, when study of the "man-machine" system becomes a steadily more urgent problem, the uncovering of the actual correlations found beyond the correlations prevailing within this system, is especially necessary. It is necessary, in particular, in order that engineering psychology be in a position to develop not merely as an ancillary discipline of technology, but as a leading division of the psychology of the work activity of man.

An unquestionable achievement of Soviet psychological science is the overcoming of the unilateral, naturalistic approach to man, the interpretation of human psychics as a product of social-historic development. In concrete investigations of psychic activity of man such an interpretation was realized for the first time by L. S. Vygotskiy ("Development of Higher Psychic Functions", 1960). This approach retains, of course, all

of its value also in work psychology; it should be also extended to include problems of engineering psychology. Man is, of course, a natural being. However, as a social subject he exhibits particular characteristics; which also involves a change in the type of his development, and of the laws which govern it. This is the result of the specific nature of his activity, which resides in the fact that it is a productive activity. Of such a nature is primarily the basic human activity -- the work activity.

The work activity of man is embodied in its product; it is converted to the form of subsistence or objectification (see K. Marx "Capital", Vol 1, 1955, pp.187-188). At the same time in the tools by means of which it is achieved, man acquires virtually new organs, which, in the words of Marx, he adds to the organs of his body.

Thus, man appears in history as a subject of work activity, of a process by means of which he actively controls the material interchange between him and nature, and, on setting his cognized goals, he effects predetermined changes in the work object. Although the combined faculties which man exercises in this connection, include necessarily his physical force, the latter is only practically realizing in the product of work that aspect of this process which constitutes its psychological tenor. In other words, man manifests himself in the work activity as a subject endowed with psychics, with cognition. By embodying his intentions in the work he not only overcomes the inertness of natural matter, creating tools and machines, but overcomes also the "biological inertness" of his natural organs, of his natural forces and faculties. Therefore the development of man during the progress of the social-history process proceeds at a rate which is completely incommensurable with the rate of his biological evolution. Let us consider this process in somewhat greater detail.

Every individual person enters life under conditions created by the preceding generations. But these conditions are not, by any means, a mere environment in relation to man, to which he must adapt himself; in the form of objective things and phenomena, these conditions carry within themselves the achievements of the historical development of people, the experience of social practice, the combination of the human faculties shaped in the course of history. In order to live in society man needs more than that with which nature has provided him at birth. He must also master the experience gained in the course of social history, which is embodied and objectified in the environment of the human world -- a world of industry, sciences and arts. This applies primarily to mastering of

work tools, which constitute the typical, material form of crystallization of human activity.

A tool is not merely a physical object having definite mechanical properties. It is at the same time also a social object, an object in which are embodied and consolidated the ways of action evolved in the course of history -- the working operations. The existence of this social and at the same time ideal tenor, crystallized in the human tools, differentiates them from the "tools" of animals.

Animals also perform certain operations by means of the so-called "tools". For example, it is well known that monkeys learn readily how to make use of sticks. However, the "tools" of animals, unlike real tools, do not become lasting carriers of the means of their utilization. The animals do not keep their "tools"; they are not transmitted from one generation to another, nor are they improved. Consequently, there is in animals no process of mastering of tools, of their "adoption". The use of the "tools" does not develop in them new faculties; on the contrary, the "tool" itself is subject to the natural behavior, based upon instinct, within the system of which it is included.

Quite another matter is the employment of tools by man. In the course of mastering of the tool, man conforms his motions to the socially developed system of operations which is materially consolidated in it. The tool causes a rearrangement of the behavior of man, and develops new faculties in man during his life. "... Adoption of a definite set of production tools -- says Marx -- is equivalent to development of a definite set of faculties in the individuals themselves" (K. Marx and F. Engels, Works, Vol 3, page 68).

The same thing takes place when man masters the phenomena of spiritual culture. For example, mastering of a language is the result of those mental operations which have been historically consolidated in its meanings. It is obvious that in the course thereof also takes place a mastering of the operations as a result of which is realized the uniformity of the grammatical and phonetic system of the given language.

Thus, the same as the faculty of achieving activity with the use of tools, the speech activity of man, his speech-motive and auditory functions, arise as a result of his mastering, in the course of the process of ontogenetic development, of the achievements of historical development of humanity, embodied in the objective world that surrounds him.

The type of development inherent in man puts him

in a particular relationship with the world in which he is living. Adaptation to the environment loses in man its direct, biological character. The world of human objects and phenomena, which is nearest and most important to man, confronts him not as an environment to which he must adapt himself, but as something which he makes his property, and by means of which he achieves his life.

Thus, the development of man's activity in a society is, in a way, extending beyond the limits of his being. This is, of course, only a metaphoric expression. However, it shows a most important fact. This fact is, that to man, tools and machines, language and science, are organs of his activity -- of outward activity as well as of inner, mental activity. And this is true to such an extent, that if man is deprived of these organs, he is found to be fully devoid of capability for any human activity whatsoever.

On the other hand, the removal of man would convert the world which he has created to a mere clutter of slowly, but unavoidably decaying objects; their fate would be the same as the fate of anatomy organs severed from the human organism. In other words, behind this "ready-made" world continues to stand man, as its basically irremovable subject.

The relationships which we have described appear under the conditions of a class society only as the relationships of an abstract, "integral" man. On the other hand, the real man is found to be facing, under these conditions, the world of material and spiritual values created by mankind, as an alien force which subjugates him. These relationships become for the first time the true relationships between men only in our era, the era of consolidation of socialistic communist society, which liberates human labor. It is these relationships that determine the prospective development of human activity and of man himself.

The approach to man which ensues from these prospects, alters substantially the nature of the psychological problems. The work activity of man reveals in the light of these prospects its full tenor, and appears as the principal form of his activity, which is becoming steadily more "reintegrated", and including the diverse manifestations of human psychics. Therefore the psychology of work ceases to be a specialized branch of psychology and its theoretical problems become also the major problems of general human psychology. This also means, however, that the psychology of work can no longer develop on the "butts" of psychological science, as was the case within the framework of the former psychotechnology.

4

Development of mechanization and automation is necessarily intellectualizing the work functions of man. However, under the conditions of capitalistic production this process is hampered. On the other hand, in socialist society, where the overcoming of the breach between physical and mental work is becoming one of the major social problems, it acquires full freedom for its development. This refers not to a mechanical combining of external, practical activity and the inner, mental activity, but to their merging, to their mutual permeation. This poses a psychological problem which from the standpoint characteristic of idealistic psychology is fundamentally irresoluble.

It is well known that this standpoint is based upon a contrasting of phenomena and processes of two different kinds. One kind consists of material processes and phenomena, which include also the outward activity of man and the physiological processes which effect it. The other kind consists of the inner, subjective processes and phenomena of thinking, imagination, etc. It is alleged that it is solely they that constitute the sphere of psychics. It is obvious that from this standpoint any outward activity is fully outside the field of vision of psychological research.

This question is being resolved in a quite different manner from the standpoint which was first developed in orderly succession in Soviet psychology. The differentiation upon which it is based is differentiation of material subject, of that objective reality with which this subject is interacting, and finally of the processes that effect this interaction. At a certain stage of evolution these processes, which have become of infinite complexity, acquire a structure which renders possible such an "unfolding" of them in the brain of the subject as to constitute the image, the psychical reflection, of the reality acting upon the subject.

Since these processes are, in practice, connecting the subject with the reality that surrounds him, they are necessarily subordinate to its objective characteristics, associations and relations; hence, just as necessarily are subordinate to them also these reflections in the brain. Only at the still later stages of development -- at the level of man -- are the processes which connect the subject with the surrounding reality, and which at the same time effect its "translation" into psychical reflection, capable of acquiring also the form of inner, cognizing activity. They remain, however, the processes which effect the real life of the real, material subject;

being a derivate of outward, practical activity, they, in turn, serve as an intermediate to it.

The theoretical views briefly outlined above, fully eliminate the contrasting of inner, mental activity and the outward, practical activity, which is characteristic of the obsolete, idealistic psychology. Thus these views open up the way to investigation of their actual inner correlations and make it possible to advance the hypothesis of a fundamentally common structure of outward and inner activity (see A. N. Leont'yev, Problemy Razvitiya Psikhiki [Problems of Development of Psychics], 1959).

This hypothesis arose on the basis of experience with analysis of developed, intermediated by psychical reflection, forms of activity inherent in man. Such an analysis requires the differentiation in the complex picture of the system of human activity, taken as a whole, first of all its most general "units" -- the separate activities. We denote by this term the complex combination of processes united by a common direction toward the achievement of a definite result, which constitutes at the same time the objective incentive of a given activity, i.e., that which concretizes (in which is "objectivated") some need of the subject. The result, to the achievement of which is directed the activity of the subject may be of a directly practical nature, or of a idealistic, theoretical nature. It is evident that in the former instance of main significance in the activity will be outward, motive processes; in the latter case, the inner, mental processes. In order to determine the correlation of these processes it is necessary to extend somewhat the analysis.

Achievement of the result inducing some activity of the subject, assumes the performance of a number of actions which constitute the tenor of a given activity. These are relatively independent processes, subordinate to a cognized purpose (if the result of the activity is cognized as the ultimate goal, then the purpose of the action is cognized as an intermediate goal). In contrast with the activity, the actions correspond not to an independent motive, but to the motive of the activity in the tenor of which they are included. The relative independence of an action is exhibited by the fact that the same action can effect different activities; it varies only in its motivation and in accordance with the meaning which it has to the subject.

From the standpoint of the problem under consideration, it is important to emphasize that actions can also be either outward, practical, or inner and mental. Thus the tenor of practical activity not infrequently includes mental actions, and the tenor of a theoretical activity

may include outward and practical actions (for example, in adjusting a laboratory unit the investigator carries out a practical action, but it is a part of his theoretical investigative activity).

The third "unit" which should be differentiated is the procedure by which the action is carried out; that which we call an operation. The operations, which in a way are the "technical" components of actions, are also relatively independent. In effecting the action they correspond to its conditions and not directly to its purpose. Therefore the same operations may effect different actions, outward as well as inner, mental. At the same time the operations themselves may be inner, mental (for example calculations "in our head").

Thus the structural units which we have differentiated can be, first, of the form of outward processes as well as of the form of inner processes. Secondly, they can change from one form to the other; for example, the directly productive work activity can include in its tenor a large number of inner actions, such as, mental comparison of indicator readings, all kinds of computations, etc. All this gives reason for asserting the common structure of outward and inner activity. However, in a deeper sense this common nature is revealed only on examination of the genetic correlations which interconnect the outward and inner actions and operations.

These correlations, as is shown by present-day studies, are characterized by the fundamental fact that the inner mental actions and operations arise from the outward; that they are the result of the process of interiorization of the latter. We know that the process of interiorization had been described by many psychologists. This process is most complex and we can not, of course, undertake its detailed analysis. We will limit ourselves to the consideration of only two questions: the question concerning the necessity which induces this process, and the question of formation of mental actions.

It may be considered as generally accepted that the mental, thinking activity is formed in man during the course of his ontogenetic development. However, up to now this process is often visualized in an extremely simplified manner. It is assumed that the thinking, logical processes develop in man in the same manner as the analytic-synthetic activity develops in higher animals, and that all the difference between them is: first, that in man the thinking processes are formed under conditions of the influence upon him of phenomena of a social nature, including the effects of speech -- stimuli of the second signal system; secondly, that in man this process takes place under the influence of training, which presents to

the learner a systematically selected and properly correlated material. As a result, due to repetition and reinforcement of these correlations, there are formed in him such associations, combined into complex systems, the actualization of which constitutes precisely his thinking activity.

Notions of this kind, although attractive by their apparent simplicity, are in manifest conflict however with the facts. They conflict, first of all, with the real rate of progress of a child's thinking. Indeed, the formation of mental, logical processes, developed during the many centuries of social-historical practice of mankind, by formation and generalization of correlations, arising under the influence of an even specially selected material, would require many, many life-spans. Actually, this process progresses very rapidly and on the basis of a material incomparably more restricted than the minimal necessary for the above-described process.

A still more serious difficulty, encountered by the simplified scheme of ontogenetic development of the thinking activity, under consideration, is the fact that it is possible, for example, fairly readily to develop in a child associative correlations of the type $3 + 4 = 7$, but a correct actualization of these correlations by a child is not at all an evidence that he has mastered the arithmetical operation of addition; it may be found that he can not count at all. The gist of the matter is, that it is not the operation of addition which is the product of these correlations, but just the opposite -- these correlations are the products of mastering of this operation. Therefore the teaching of addition never starts with a learning of tables of addition, nor does it consist in it. The child is taught to perform the operation of addition, that is, this action is actively developed in the child. It is only subsequently, as a result of a complex process of transformation of this action in the child's head, that he develops the apparently elementary associations of the above-stated type.

But, how can a mental action be formed? The corresponding process must undergo formation in the child's head, but as previously stated this can not take place by itself under the influence of those objective phenomena to which this process corresponds. For example, the influence of empirical sets can not bring about the formation of mental computation. Mental actions can be formed only by means of mastering the historically evolved actions. In other words, the actions must be actively built in the child, and in every man, by the surrounding people. But to build directly a mental action, that is an action the

essential tenor of which consists of processes taking place in the head, is impossible: such an action can neither be shown nor seen. Therefore the only possible way to teach a mental action is first to produce this action in the form of an outward action, with objects which are also outward, and then to transform it into an inner action.

Thus, the mental actions and operations are ontogenetically formed as a result of a mastering of them, which is possible only if they are presented in an outward form. This is precisely why the existence of a specific process of interiorization is necessary.

To date the path over which takes place the transformation of the outward actions into inner actions has been studied in sufficient detail (see P. Ya. Gal'perin "Development of Investigations on the Formation of Mental Actions" in the symposium Psikhologicheskaya Nauka v SSSR [Psychological Science in the USSR], Vol 1, Moscow, 1959).

The process of interiorization is, however, only one of the characteristic aspects of the correlations between outward and inner activities. The other aspect is exhibited in a process taking place in the opposite direction, in the process of exteriorization.

A very important characteristic of mental actions and operations resides in the fact that they are capable of changing from their inherent, concise and abridged form into an unfolded and outward form. This kind of inverse transformation of them, which is sometimes total and sometimes incomplete, is well known and constantly observed, for example in cases when difficulties arise which make it necessary to verify the action while looking at it (the solving of a mental problem "with pencil in hand", by drawing a diagram, etc.). The main thing, however, is that the transformation of mental processes into an unfolded outward form provides the possibility of their embodiment in practical activity, and of their crystallization in tools and machines, which are, according to Marx, "the man-made organs of human brain".

Thus the correlation between outward practical, and inner theoretical activity of man is characterized not only by the fact that the separate "units", which form their tenor, are capable of moving from one kind of activity into the other, but also by the fact that they are capable of mutual transformation. The significance of these mutual transitions and mutual transformations was hidden by the chasm which, in the old society, separated physical and mental work. This separation appeared to be permanent and fundamentally insuperable. Hence the psychological study of mental processes was also divorced from

their live connection with outward practical activity. For this reason it is most pertinent at the present time to develop further the study of concrete correlations, which connect thought and work, "head and hands". In our epoch of convergence of mental and physical work, it is a most important psychological problem.

5

The problem of "man and machine", which has become the center of attention in modern psychology of work, is not only a practical, but also a theoretical problem concerning the correlations between the processes effected by machines, on the one hand, and by human activity, on the other. From the standpoint of man taking part in the process of production, even the most modern machines, including those provided with automatic control devices, are merely a technical means, a method of effectuation of productive activity. Man consigns to them a vast number of functions which in their combined complexity are beyond his power. These functions, however, are created by man, and in this sense they are transformed and objectivated human functions.

As was stated before, any operations, regardless whether outward-motive or mental, are parts of the tenor of action as means of its effectuation. On the basis of their origin they are transformed actions. This transformation occurs when an action becomes a part of another action which is more complex and may be termed a "higher" action, in relation to the first. As a result, a formerly relatively independent action is gradually "algorithmized" and "automated". Thus, for example, the formation of a motive technique (motive skill) begins, as we know, with its mastering in the form of a cognizably performed action. Then this action is included in a more complex, integral action, within which it acquires the final "finish", after which it is performed more or less automatically. In the same manner are also formed all mental operations, with the only difference that in this case the initial action also undergoes interiorization.

Figuratively speaking, the formation of an operation is the dying of a formerly creative action. In the operation are retained and become fixed only those structural correlations of an action which reproduce the objective correlations of the objective conditions of its performance. These objective correlations are not, of course, psychological; that is the very reason why they can be embodied in an objective form, in the form of objective products of human activity, and separate

from man. Thus they acquire their own objective existence and development.

Such are all human tools, in which are crystallized the work operations; such are the words of a language, which carry within their meanings the mode of their usage; such are, finally, the laws and formulas of logic and mathematics.

Do the technical devices of cybernetics constitute an exception in this respect? They are capable of performing any, even the most complex, mathematical and logic operations. Man can convey to the machine diverse functions of his brain, on the condition however that they are adaptable to formalization; otherwise they can not be technically simulated. But the functions which meet this condition are nothing but operations; they are processes which have already been formalized, "technicized", so to speak, in the brain.

One often speaks of machine activity, of actions performed by the machine. A description of the work of machines in these terms is justified by the fact that the system of processes which they effectuate appears to be fully coincident with the human action which this system is simulating. Indeed, if we consider as the "unit" of action analysis an operation (or, all the more, some unit differentiated on more detailed analysis), we can obtain as a result their full mutual superposing. The fact is that operations, as we had emphasized hereinbefore, do not add to the tenor of an action, but form its tenor. In other words, on mentally subtracting from the action the operations which effectuate it, we exhaust thereby all of its tenor. There remain only the cognizance of the purpose of the action, its motivation and its meaning to the subject, which depend upon the activity which he carries out, and the respective "emotional sign" of the given action -- all that which constitutes its "psychological remainder" and imparts to the action a live, predilected character.

Thus, the machine reproduces not the action, but only a system of operations which constitute its tenor. Does this put a limitation to machine capabilities? We believe that this question should be separated into parts. If we are talking about the capability of a machine to cognize the purpose and meaning of the action, of actively to differentiate these purposes in accordance with requirements and motives, then in the framework of nonliving matter the answer to this question must be negative. On the other hand, if we are considering the potentialities of the machine to effectuate all of the complex systems of mental processes, we must admit that

these potentialities are boundless and encompass also processes which are far beyond the scope of the known operations.

This contention is by no means in conflict with the proposition that only operations can be technically simulated. We have mentioned before that operations are the product of transformation of the action, occurring under the conditions of its inclusion as a component into a more complex, "higher" action. Consequently, that which today appears in human thinking as a creative action which can not be formalized, may tomorrow become an operation. Hence there are also no boundaries which limit the development of more and more "intelligent" machines. We should only abandon that approach to this problem which, while boldly extrapolating into the future the technical developments, regards at the same time the mental potentialities of man as stationary and not developing. When man consigns to the machine the performance of operations, he is not merely unloading his brain. The machine is a means of work, a "conductor" of human activity and, like any means of work, it provides him with equipment. Therefore, when man delegates his functions to the machine, the machine, in turn, is in a way imparting to man the functions which it fulfills. For example, in utilizing a computer for processing of necessary data, man is not only consigning this function to the machine. By utilizing the results of its functioning, man widens his mental capabilities, can solve problems which could not be solved without employment of the machine. At the same time, the functions which man consigns to the machine are not merely reproduced by it, but are greatly accelerated, become more complex and widen their limits. Also, that which the machine contributes by its work to human activity, brings about the formation of new faculties in man, of new functional systems of his brain, which constitute "mobile physiological organs" (Ukhtomskiy) of these faculties.

In psychology of work activity of man these circumstances are of importance because they emphasize the significance not only of the problem of adaptation of the machine to man, but also of the problem of active formation of psychical faculties of man in accordance with the demands made upon him by technical progress, and with the potentialities which it affords him.

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